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MOSQUITOES AND MALARIA IN BRITAIN

By Colonel Sir Ronald Ross, K.C.B., F.R.S., Consultant in Malaria, War Office.

Twenty years ago, when I was endeavouring to find the route of infection in malaria, I was informed by the authorities of the Indian Museum in Calcutta that nothing was then known regarding mosquitoes in India; and, in fact, I had been obliged to work out for myself all the knowledge which I possessed on the subject. Even in Europe and America, studies on the Culicidas were at that time very scanty and incomplete—with the exception perhaps of the work of Ficalbi in Italy. When, however, malaria, and afterwards yellow fever, were shown to be carried by certain species of mosquitoes, the science of Konopsology (to use a barbarous word, I fear, of my own!) grew apace. Many capable observers studied the insects all over the world, and between 1900 and 1911 Mr. F. V. Theobald produced his great Monograph of the Mosquitoes of the World—a work which was, I believe, of prime imperial importance. Nor have such investigations diminished during the war.

As, however, I am not an entomologist I think it will be more useful if I make some brief remarks to-day on the subject of mosquitoes and malaria in Britain rather than on mosquitoes alone.

The first work on this subject in the light of recent discovery was done by Nuttall, Cobbett, and Strangeways-Pigg, and by Nuttall and Shipley, who published a series of admirable papers in the Journal of Hygiene for 1901 and 1902. These authors pointed out that though malaria had been formerly prevalent in Britain but had then died out, Anophelines continued to exist,

though possibly in diminished numbers, in places which had been previously afflicted by the disease. They published maps of the distribution both of Anophelines and previous malaria, and discussed the question why it was that this malady had left Britain in such a mysterious manner.

Sir Clifford Allbutt once told me that he saw numerous cases in Cambridge in 1860. I saw a case at St. Bartholomew's Hospital in 1879. Nuttall, Cobbett, and Strangeways-Pigg verified a case which had occurred at Norwich in 1898 (Journal of Hygiene I, 1, page 31). Copeland and Smith described a case at Portsmouth in 1906 (Journ. R.A.M.C., August, page 186), and Easton a case at Aldershot in 1909 (*Ibid.*, November, page 585)—both cases being soldiers. Except for these cases the disease appeared to have died out entirely of recent years in Britain, and when I wrote to the medical press for further information I received none at all. More recently, however, evidence has been found to suggest that malaria has really continued all the time to be endemic to a very small degree in certain parts of Kent; and then, last year, a certain number of cases undoubtedly occurred in various low-lying parts of this country.

This is why I venture to speak to you on the subject to-day. On the one hand, some people may make light of the whole subject in view of the extremely small prevalence of malaria in Britain during the last fifty years at least; but, on the other hand, alarmists may be seriously disturbed by the possibilities of a graver prevalence. What are the real factors engaged in the existence, the increase, the diminution, or perhaps the extinction, of malaria in a country? My remarks will be confined to this item.

Of course, many writers have discussed the question at length during the last twenty years. But few have understood that it is really a mathematical question.

The propagation of all communicable diseases through a population is, I say, really a mathematical question, like that of the propagation of heat or electricity, or light through a medium. It is easy to say that one or another factor may influence the final result; but this is not enough of itself because we must also determine *how much* each factor influences the final result, and to what degree one factor is bound up with another factor. In other words, we must think quantitatively as well as qualitatively; and this method of thinking has the advantage that it forces us to consider each possible factor in the spread of a disease most minutely and exhaustively. I believe that the first study of malaria along these lines was made by myself in my book on the Prevention of Malaria (John Murray, 1910, and second edition, 1911); and I came to the conclusion that the spread of malaria in a community must depend upon about fifteen different factors.

Now, I am aware that biologists are seldom mathematical—have indeed been known to boast of being not mathematical. Hence I will not trouble you to-day with quantitative reasoning, but will content myself with a brief qualitative statement.

First, we must of course assume as being abundantly proved that the parasites of malaria are carried from an infected person to a healthy person by a mosquito of the proper species—an Anopheline. But consider what this means with regard to the number of Anophelines which must be present. Of all the millions bred in a locality possibly only a few can ever succeed in biting a human being at all. Then only a proportion of these will generally have bitten an *infected* human being; and again, only a smaller proportion will have bitten an infected person whose blood contains sexual parasites suitable for transmission into a mosquito. Hence the chances usually are that only a very small proportion of all the Anophelines in a place will ever

become infected at all. But how many of these will infect healthy persons? A mosquito must live for about ten days at least before the parasites can mature in her body and enter her salivary glands, and of the small proportion of mosquitoes which may live long enough for this a still smaller proportion are likely to succeed in biting and infecting healthy persons afterwards. Hence a very small proportion of the Anophelines in a locality are generally likely to infect healthy persons. *Per contra* if healthy persons *are* infected in a locality a large number of Anophelines must generally be present there. The problem is one in the Calculus of Probabilities, and is like that of the number of bombs made in Germany which are ever likely to hit English people. Indeed, the mosquito is very like an aeroplane: the same kind of weather suits both of them, and the mosquito brings along malaria zygates attached to its stomach just as an aeroplane brings bombs!

But on examining the problem more deeply we shall find that the broader constants can be split up into many minor but fundamental factors. Thus both men and mosquitoes may vary in individual resistance to parasites—especially if the men are being given quinine. Both men and mosquitoes will be infective to each other only at certain times when the parasites are ready for transference. A proportion both of men and of mosquitoes will be constantly recovering from infection. The "biting factor" is a very important one: mosquitoes will more readily bite naked, unprotected, sleeping or crowded persons, and in hot weather. Lastly, to be quite accurate, we have to deal with the birthrates and the deathrates, the immigration and the emigration both of men and of mosquitoes. Thus, long-lived mosquitoes are likely to do as much harm as more numerous short-lived ones. Hence the general equations given on page 679 of my book (second edition) for diseases common to two species of hosts contain fifteen indepen-

dent constants, or rather parameters, namely, the birth-rate, deathrate, immigration, emigration, immunity, infectivity, and recovery ratios for each species of host, and the contact ratio (biting factor in malaria) common to both; and the total proportion of infected individuals of either species must depend on all of these combined in certain mathematical "functions."

Some of these factors are probably nearly constant everywhere in each species considered (for a given kind of parasite); but others will vary from place to place and time to time, and others again may be artificially modified—such as the deathrate of mosquitoes, the immunity and infectivity of men by quinine, and protection against biting by netting, clothing, partition walls, glass windows, etc. These artificial modifications constitute the methods which we possess for preventing malaria. The disease probably died out in England owing to a modification of several factors, as by drainage, the more general use of quinine, better housing in agricultural districts, and quite possibly by some unknown cyclical variation of climate (of which we yet possess no evidence).

The increase of cases of malaria in England last year was probably caused partly by an increase of infected immigration due to the war, partly, I suspect, by an exceptionally fine year for the breeding of Anophelines, and partly by the increase of congregate sleeping. We shall be in a better position to consider this matter at the close of the present year.

Those who would like to know what precautions are being taken against the spread of malaria in England will find the facts set forth in the *Lancet* and in an excellent leading article in the *British Medical Journal* for May 25th, 1918, and in a forthcoming report of the Local Government Board.

In conclusion I should like to ask all those present who are able to do so to take special interest in the

bionomics and distribution of Anophelines in Britain: they will thus serve not only entomology but also the cause of hygiene. I am sure that the War Office, the Local Government Board, the Admiralty, the British Museum, and the Imperial Bureau of Entomology (at the British Museum) will welcome any additions which they may make to this branch of science. I may add that the British Museum has now published an extension of the map showing the distribution of Anophelines in Britain originally produced by Nuttall, Cobbett, and Strangeways-Pigg in 1901—a map which will be useful to all workers on the subject.

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